



BSI Standards Publication

Geographic information — Schema for coverage geometry and functions

Part 1: Fundamentals

National foreword

This British Standard is the UK implementation of EN ISO 19123-1:2023. It is identical to ISO 19123-1:2023. It supersedes BS EN ISO 19123:2007, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee IST/36, Geographic information.

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European foreword

This document (EN ISO 19123-1:2023) has been prepared by Technical Committee ISO/TC 211 "Geographic information/Geomatics" in collaboration with Technical Committee CEN/TC 287 "Geographic Information" the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2024, and conflicting national standards shall be withdrawn at the latest by January 2024.

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 211, *Geographic information/Geomatics*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 287, *Geographic Information*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement), in collaboration with the Open Geospatial Consortium (OGC), and in collaboration with the IEEE GRSS Earth Science Informatics Technical Committee.

This first edition cancels and replaces ISO 19123:2005, which has been technically revised.

The main changes are as follows:

- the document has been renamed as “Part 1: Fundamentals”, since a new “Part 2: Coverage Implementation Schema” has been published;
- the text has been simplified for better understanding;
- concepts, while in principle unchanged, have been defined more rigorously and some errors have been corrected;
- the approach to standardization taken in this document has been changed. This edition of the document defines a high-level, generic concept of coverages with an interface definition from which many different (not necessarily interoperable) implementation structures can be derived. The previous edition of this document, ISO 19123:2005, defined a single generic data structure for coverages. The previous model remains valid as one of the many possible data structures that can implement the ISO 19123-1 interface. This data structure, which is defined in [Annex D](#), supports backward compatibility. Standardization targets that referenced ISO 19123 can continue referencing those same classes, although new realizations are not encouraged to do so. It is noted, however, that the coverage definition terms in [Clause 3](#) which are owned by other documents have been updated to refer to newer editions of the documents (including their definitions) where such newer editions are available;

- all operations except *evaluate()* have been removed, for simplification purposes. ISO 19123-3 now specifies the operations requirements;
- the Scope has been extended to include Mesh;
- the concept of discrete and continuous coverages has been generalized to achieve an improved conceptual basis and to allow for coverages which are discrete along some domain axes and continuous along other domain axes. This is achieved by using the coordinate reference system axes as the basis for the definitions so that any axis individually can be discrete or continuous. Since this is a generalization of the previous concept it is backward compatible. As a side effect, this reworking has greatly simplified the structure of this document;
- updates in ISO 19103 have been reflected, and corresponding adjustments have been made where necessary. The informative Annex on “UML notation” has been deleted since UML notation is now described in ISO 19103;
- all coordinate-related definitions are based on ISO 19111, and corresponding adjustments have been made to this document as necessary;
- the definition of image CRS has been moved from ISO 19111 to this document;
- the definition of interpolation is based on the interpolation definition of ISO 19107 in order to avoid duplicate and diverging definitions;
- the UML diagrams have been redrawn for clarity, in order to correct errors, and to follow the new conventions established in ISO/TC 211;
- the bibliography has been revised to include additional references and has been reformatted.

A list of all parts in the ISO 19123 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document defines, at a high, implementation-independent level, the notion of coverages as digital representations of space-time varying phenomena, corresponding to the notion of a field in physics. Such coverages can be discrete or continuous.

Historically, geographic information has been treated in terms of two fundamental data types called "vector data" and "raster data".

"Vector data" deals with discrete phenomena, each of which is conceived of as a feature. The spatial characteristics of a discrete real-world phenomenon are represented by a set of one or more geometric primitives (points, curves, surfaces or solids). Other characteristics of the phenomenon are recorded as feature attributes. Usually, a single feature is associated with a single set of attribute values. ISO 19107 provides a schema for describing features in terms of geometric and topological primitives.

"Raster data", on the other hand, deals with phenomena that vary over space and time, mathematically described by "fields". It contains a set of values, each associated with one of the elements in an array of points or cells. Raster data is often associated with a method for interpolating values at spatial positions between the points or within the cells.

The coverage concept, originally adopted from the Abstract Specification of the Open Geospatial Consortium (OGC),^[15] generalizes these and further data structures, such as point clouds, into a model for representing phenomena that vary continuously over space and time, and possibly over further dimensions such as spectral bands. Formally, a coverage is a function from a spatial (such as horizontal x and y and vertical height or depth), temporal, other (in ISO 19111:2019 nomenclature: parametric) domain or any combination thereof to values of some data type.

A coverage consists of a set of spatio-temporally extended geometric (often geographic) objects, each with associated attribute values. The spatio-temporal locations with which attribute values are associated are called "direct positions".

Formally, a coverage itself is a subtype of a feature as defined in ISO 19101-1. The coverage feature is a set of features all sharing some key properties, such as the same attribute definition and coordinate reference system.

NOTE Direct positions can be of different dimensions. For example, in a raster image modelled as a coverage, the direct positions will be the grid points; in a multi-solid coverage a direct position is given by the interior of a 3D solid.

In practice, coverages encompass regular and irregular grids, point clouds and general meshes. Examples include raster data, point clouds, meshes such as triangulated irregular networks and polygon sets. Coverages are multi-dimensional, including examples such as 1D sensor timeseries, 2D satellite images, 3D $x/y/t$ image timeseries and $x/y/z$ geophysical voxel data, and 4D $x/y/z/t$ climate and ocean data. Coordinate axes of such coverages can have spatial, temporal, or any other meaning, and they can be combined freely for n -dimensional coverages.

EXAMPLE The electromagnetic spectrum is an example of an axis with neither spatial nor temporal semantics. Such a spectral axis can be defined as a "parametric CRS" as established in ISO 19111.

A coverage which provides values only at the direct positions is called "a discrete coverage". If interpolation information is added so that values can be obtained also between the coverage's direct positions, such a coverage is called "a continuous coverage".

Just as the concepts of discrete and continuous phenomena are not mutually exclusive, their representations as discrete coverages are not mutually exclusive. The same phenomenon can be represented as either a discrete feature or a coverage, depending on the particular context and requirements. A city can be viewed as a discrete coverage that returns a single value for each attribute, such as its name, area and total population, but it can also be represented as a continuous coverage that returns values such as population density, land value or air quality index for each location in the city.

A coverage, moreover, can be derived by bundling a collection of discrete features sharing a common attribute definition, the values of the coverage at each position being the values of the attributes of the feature located at that position. Conversely, a collection of discrete features can be derived from a coverage by extracting all direct positions with their associated attribute values.

The previous edition of this document, ISO 19123:2005, addressed coverage modelling on both a conceptual and (to some extent) an implementation level, effectively mixing both. Coverage modelling has now been split into two separate, but related documents: ISO 19123-1 (this document), which establishes an abstract, high-level coverage model, and ISO 19123-2, which establishes an implementation-level model ensuring interoperability, based on the concepts of ISO 19123-1. A corresponding high-level processing model for coverages is defined in ISO 19123-3.

Geographic information — Schema for coverage geometry and functions —

Part 1: Fundamentals

1 Scope

This document defines a conceptual schema for coverages. A coverage is a mapping from a spatial, temporal or spatiotemporal domain to attribute values sharing the same attribute type. A coverage domain consists of a collection of direct positions in a coordinate space that can be defined in terms of spatial and/or temporal dimensions, as well as non-spatiotemporal (in ISO 19111:2019, “parametric”) dimensions. Examples of coverages include point clouds, grids, meshes, triangulated irregular networks, and polygon sets. Coverages are the prevailing data structures in a number of application areas, such as remote sensing, meteorology and mapping of depth, elevation, soil and vegetation. This document defines the coverage concept including the relationship between the domain of a coverage and its associated attribute range. This document defines the characteristics of the domain. The characteristics of the attribute range are not defined in this document, but are defined in implementation standards. Consequently, the standardization target of this document consists of implementation standards, not concrete implementations themselves.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 19103, *Geographic information — Conceptual schema language*

ISO 19107, *Geographic information — Spatial schema*

ISO 19111, *Geographic information — Referencing by coordinates*

3 Terms, definitions, abbreviated terms and notation

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1.1

analytical coverage

coverage where the mapping function from domain to range is given by an analytical mathematical function

3.1.2

axis

<coordinate geometry> tuple of axis name, axis abbreviation, axis direction, axis unit and further information

Note 1 to entry: This definition is established in accordance with ISO 19111:2019, Table 26 and subclause 10.4.

Note 2 to entry: Inside a coordinate reference system (CRS) containing several axes the axis names are required to be pairwise different.

Note 3 to entry: The axis unit (of measure) defines the set of values which can be used as a coordinate along this axis. These can be numbers (such as in Latitude and Longitude) or general strings (such as in timestamps or special identifiers like “FL100” in aviation).

3.1.3

cell

<coverage> neighbourhood around a direct position in a coverage grid, not overlapping with any other direct position neighbourhood in the coverage grid

Note 1 to entry: Coverage cell is synonymous to grid cell.

Note 2 to entry: All cells of a grid coverage together establish a tessellation (i.e. complete, overlap-free cover) of the grid space.

3.1.4

continuous coverage

coverage that returns values for both direct positions and positions between direct positions

3.1.5

coordinate

one of a sequence of measures designating the position of a point

Note 1 to entry: In a coordinate reference system, the coordinate numbers are usually qualified by units. Some coordinates may use a unit representation, for example date/time conformant with ISO 8601-1. When coordinates are an index (ordinal coordinates) they are unitless (which possibly can be represented by a unit of 1).

[SOURCE: ISO 19111:2019, 3.1.5, modified — Original note 1 to entry has been amended.]

3.1.6

coordinate reference system

coordinate system that is related to an object by a datum

[SOURCE: ISO 19111:2019, 3.1.9, modified — Notes 1 and 2 to entry have been deleted.]

3.1.7

coordinate system

set of mathematical rules for specifying how coordinates are to be assigned to points

Note 1 to entry: A coordinate system contains an ordered sequence of one or more axes; their names are required to be pairwise different.

[SOURCE: ISO 19111:2019, 3.1.11, modified — Note 1 to entry has been added.]

3.1.8

coordinate tuple

tuple composed of coordinates

Note 1 to entry: The number of coordinates in the coordinate tuple equals the dimension of the coordinate system; the order of coordinates in the coordinate tuple is identical to the order of the axes of the coordinate system.

[SOURCE: ISO 19111:2019, 3.1.13]

3.1.9**coverage**

function which returns values from its range for any direct position within its domain

3.1.10**coverage coordinate reference system****coverage CRS**

coordinate reference system (CRS) in which all coordinates in a coverage domain are expressed

Note 1 to entry: Sometimes a coverage's CRS is also referred to as the coverage's native CRS to express that this is the CRS to which all the coverage's location data refer.

3.1.11**coverage dimension**

<coordinate geometry> number of separate decisions needed to describe a direct position in a coverage domain

Note 1 to entry: This is equivalent to "the number of axes in the coverage domain CRS".

Note 2 to entry: This definition is based on the term "coordinate dimension" defined in ISO 19107:2019, 3.17.

3.1.12**coverage geometry**

domain of a coverage described in terms of geometric objects

3.1.13**Delaunay triangulation**

network of triangles such that the circle passing through the vertices of any triangle does not contain, in its interior, the vertex of any other triangle

3.1.14**direct position**

<coverage> position inside one of the geometric objects in a coverage described by a coordinate tuple within the coverage coordinate reference system

Note 1 to entry: A direct position is described by an ordered sequence of coordinates. The number of elements in a direct position is established by the number of axes of the coverage CRS.

Note 2 to entry: This is consistent with the definition in ISO 19136-1:2020, 3.1.20.

3.1.15**discrete coverage**

coverage that returns value only for the direct positions within its domain

Note 1 to entry: Discrete coverages have values only for their direct positions, whereas continuous coverages can be interpolated, thereby providing values between direct positions in addition.

3.1.16**domain**

<coverage> set of geometric objects

Note 1 to entry: Examples of such geometric objects are points, lines, faces and solids. All elements within a domain (set) are of a single given type.

3.1.17**external coordinate reference system**

coordinate reference system whose datum is independent of the object that is located by it

Note 1 to entry: This term is kept only for backwards compatibility and is not used in nor fundamental to the coverage definition of this document.

[SOURCE: ISO 19130-1:2018, 3.25, modified — Note 1 to entry has been added.]

3.1.18
evaluation

<coverage> determination of the values of a coverage at a direct position within the domain of the coverage

3.1.19
feature

abstraction of real world phenomena

[SOURCE: ISO 19101-1:2014, 4.1.11, modified — Note 1 to entry has been removed.]

3.1.20
feature attribute
characteristic of a feature

Note 1 to entry: The value associated with a direct position. Also known as “feature property” and may support potential attribute, quality, or characteristic of a feature.

[SOURCE: ISO 19101-1:2014, 4.1.12, modified — Original notes to entry and examples have been deleted and a new Note 1 to entry added.]

3.1.21
function

<mathematics, programming> rule that associates each element from a domain (“source domain”, or “domain” of the function) to a unique element in another domain (“target domain”, “co-domain” or “range” of the function)

[SOURCE: ISO 19107:2019, 3.41]

3.1.22
geometric dimension

<geometry, topology> largest number n such that each point in a set of points can be associated with a subset that has that point in its interior and is topologically isomorphic to $\mathbb{E}^n$, Euclidean n -space

[SOURCE: ISO 19107:2019, 3.48 modified — Original notes to entry have been deleted.]

3.1.23
geometric object

<geometry> spatial object representing a geometric set

Note 1 to entry: A geometric object consists of a geometric primitive, a collection of geometric primitives, or a geometric complex treated as a single entity. A geometric object may be the spatial representation of a feature object.

[SOURCE: ISO 19107:2019, 3.49]

3.1.24
geometric set
set of direct positions

Note 1 to entry: A geometric set describes a single geometric object. The domain of a coverage consists of a set of such geometric objects. In the case of point clouds and grid data where each geometric set consists of only one single point, the domain is a set of these direct positions. For higher-dimensional geometric sets, such as curves, surfaces and solids, the set can be described through other means than enumeration, such as Boundary Representation or constructive solid geometry (CSG).

[SOURCE: ISO 19136-1:2020, 3.1.32, modified — Original note to entry has been deleted and a new Note 1 to entry has been added.]

3.1.25**georectified**

corrected for positional displacement with respect to the surface of the Earth

Note 1 to entry: This term is kept only for backwards compatibility and is not fundamental to the coverage definition of this document.

[SOURCE: ISO 19115-2:2019, 3.11, modified — Note 1 to entry has been added.]

3.1.26**georeferenceable**

associated with a geopositioning information that can be used to convert grid coordinate values to values of coordinates referenced to an external coordinate reference system related to the Earth by a datum

Note 1 to entry: This term is kept only for backwards compatibility and is not fundamental to the coverage definition of this document.

[SOURCE: ISO/TS 19163-1:2016, 4.9, modified — Note 1 has been added.]

3.1.27**georeferencing**

<coverage> geopositioning an object using a correspondence model mapping coverage domain elements to ground coordinates

3.1.28**grid**

<coverage> covering of a multi-dimensional region using quadrilateral shapes (in the 2D case) or their n -dimensional generation (in the n D case) with no overlaps and gaps

Note 1 to entry: The term "grid" originates historically from a 2D view: in ISO 19123 a grid consists of a network composed of one or more sets of curves in which the members of each set intersect the members of the other sets. Meantime, n D grids (including 1D) are known and in use. The "covering" of a region is also known as a "tessellation" in mathematics.

Note 2 to entry: The ISO 19123 definition is equivalent to the revised definition of this document.

3.1.29**grid coordinate reference system****grid CRS**

<coverage> coordinate reference system of a grid coverage

Note 1 to entry: This is consistent with the definition in ISO 19136-2:2015, 4.2.1.

3.1.30**grid coordinates**

<coverage> sequence of coordinates specifying a position on a grid

Note 1 to entry: This is consistent with the definition in ISO 19115-2:2019, 3.15.

3.1.31**grid coverage**

coverage whose domain is described by a grid

3.1.32**grid point**

point of a grid

3.1.33

image coordinate reference system

image CRS

engineering grid coverage coordinate reference system (CRS)

Note 1 to entry: The CRS of a raster image (without georeferencing) is a 2D grid with Cartesian axes; this special case of an index CRS is commonly referred to as "image CRS".

3.1.34

index coordinate reference system

index CRS

coverage coordinate reference system (CRS) in which all axes are Cartesian

3.1.35

mesh

geometry with associated topology of dimension greater than zero

Note 1 to entry: Geometry and topology are defined in ISO 19107. Mesh examples include curves, TINs and solids. Points (and point clouds) resemble geometries with dimension zero.

3.1.36

pixel

smallest element of a digital image to which attributes are assigned

Note 1 to entry: A pixel is the smallest unit of display for a visible image.

Note 2 to entry: This term originated as a contraction of "picture element".

[SOURCE: ISO 19101-2:2018, 3.28, modified — Note 1 to entry has been moved to Note 2 to entry and a new Note 1 to entry has been added.]

3.1.37

point cloud

collection of data points in 3D space

Note 1 to entry: The distance between points is generally non-uniform and hence all three coordinates (Cartesian or spherical) for each point must be specifically encoded.

[SOURCE: ISO/TS 19130-2:2014, 4.51]

3.1.38

point coverage

coverage that has a domain composed of points

3.1.39

polygon coverage

coverage that has a domain composed of polygons

3.1.40

range

<coverage> set of values associated by a function, the coverage, with the domain of a coverage

Note 1 to entry: This is consistent with the more generic definition of range in ISO 19107.

Note 2 to entry: Coverage range types and values correspond to the notion of feature attribute types and values.

3.1.41

raster

rectilinear grid

Note 1 to entry: The term is also used as an imprecise generic term for imagery and gridded coverage data.

Note 2 to entry: Historically, the term derives from the scanning lines display pattern on a cathode ray tube.

3.1.42**rectified grid**

grid for which there is an affine transformation between the grid coordinates and the coordinates of an external coordinate reference system

Note 1 to entry: If the coordinate reference system is related to the Earth by a datum, the grid is a georectified grid.

Note 2 to entry: This term is kept only for backwards compatibility and is not used in nor fundamental to the coverage definition of this document.

3.1.43**referenceable grid**

grid with an external coordinate reference system whose type is either geodetic or projected

Note 1 to entry: If the coordinate reference system is related to the Earth by a datum, the grid is a georeferenceable grid.

Note 2 to entry: This term is kept only for backwards compatibility and is not used in nor fundamental to the coverage definition of this document.

3.1.44**solid**

geometric set with three spatial dimensions

Note 1 to entry: This is consistent with the definition in ISO 19107.

Note 2 to entry: A solid may have further dimensions, such as time.

3.1.45**spatial object**

<topology, geometry> object used for representing a spatial characteristic of a feature

[SOURCE: ISO 19107:2019, 3.87]

3.1.46**spatio-temporal object**

object representing a set of direct positions in space and time

3.1.47**temporal coordinate reference system**

coordinate reference system based on a temporal datum

[SOURCE: ISO 19111:2019, 3.1.63]

3.1.48**tessellation**

partitioning of a space into a set of conterminous subspaces having the same dimension as the space being partitioned

3.1.49**Thiessen polygon**

polygon that encloses one of a set of points on a plane so as to include all direct positions that are closer to that point than to any other point in the set

3.1.50**triangulated irregular network****TIN**

tessellation composed of triangles

3.1.51

vector

quantity having direction as well as magnitude

Note 1 to entry: A directed line segment represents a vector if the length and direction of the line segment are equal to the magnitude and direction of the vector. The term vector data refers to data that represents the spatial configuration of features as a set of directed line segments.

3.2 Abbreviated terms

1D	one-dimensional
2D	two-dimensional
3D	three-dimensional
4D	four-dimensional
ASCII	American Standard Code for Information Interchange
CCD	charge-coupled device
CRS	coordinate reference system
CSG	constructive solid geometry
EPSG	European Petroleum Survey Group
GIS	geographic information system
OLAP	online analytical processing
TIN	triangulated irregular network
UML	unified modelling language

4 Conformance

4.1 Notation

In this document, conceptual schemas are presented in the Unified Modelling Language (UML). ISO 19103 presents the specific profile of UML used in this document.

Several model elements used in this schema are defined in other International Standards developed by ISO/TC 211. [Table 1](#) lists the other International Standards and packages in which UML classes used in this document have been defined.

Table 1 — Sources of externally defined UML classes

Prefix	International Standard	Package
EX	ISO 19115-1	Extent
GF	ISO 19109	General Feature Model
GM	ISO 19107	Geometry
	ISO 19111	Reference Systems

4.2 Interoperability and conformance testing

As an abstract standard, this document enables multiple different implementation patterns and architectures and does not define a standardized interoperable implementation. The abstract concepts described herein can be implemented in a variety of ways which are not necessarily interoperable. The same abstract coverage represented through two different implementation models will not necessarily be identical in their structure, and services following two different implementation models will not necessarily deliver equivalent results on equivalent queries or other operations. The purpose of the abstract description specified in this document is to provide an underlying consistency at the data model level that makes it possible to establish concretizing, interoperable standards.

Conformance testing is accomplished by manually validating a candidate concretization against all requirements by exercising the tests set out in [Annex A](#).

In an implementation standard based on this abstract specification, the semantics defined in this document will normally be cast into a concrete data model (describing data structures to be stored, transferred, ingested or extracted) and a concrete service model (describing the functionality of a service operating on coverages). Such derived models should be designed in an interoperable manner, i.e. allow concise conformance testing.

ISO 19123-2 is a companion standard. Based on this document (ISO 19123-1), ISO 19123-2 defines a concrete coverage model in the sense that interoperability can be guaranteed and interoperability tests (such as the OGC compliance tests on coverages^[12]) can be established.

[Annex D](#) defines an additional generic coverage data structure. This structure represents one possible data structure that is compatible with the interface defined in this document. This is the structure that was defined in ISO 19123:2005. The purpose of [Annex D](#) is to retain backward compatibility. This is because there exist other standards, from both ISO and other organizations, which make direct reference to the generic data classes that were defined in the previous edition of ISO 19123 and which now potentially reference the same classes as defined in [Annex D](#). The interface approach is more flexible, but the classes defined in [Annex D](#) are one valid structure that may be supported through the interface. A different standard referencing this document shall indicate whether it is compliant with either the clauses below or [Annex D](#).

4.3 Organization

The coverage schema is organized into the packages shown in, [Figure 1](#) and [Table 2](#). Each package establishes one requirements class. Grouping into these requirements classes has been done with a practical perspective in mind: realizations of this document can potentially be focused on particular structures, such as grid coverages or point clouds, while ignoring all the other options.

The name and contact information of the maintenance agency for this document can be found at www.iso.org/maintenance_agencies.

Table 2 — Conformance classes

Conformance class	Clause	URI
Coverage (Core)	5	https://standards.iso211.org/19123/-1/1/conf/core
Multi-Point Coverage	6	https://standards.iso211.org/19123/-1/1/conf/multi-point
Grid Coverage	7	https://standards.iso211.org/19123/-1/1/conf/grid
Multi-Curve Coverage	8	https://standards.iso211.org/19123/-1/1/conf/multi-curve
Multi-Surface Coverage	9	https://standards.iso211.org/19123/-1/1/conf/multi-surface
Multi-Solid Coverage	10	https://standards.iso211.org/19123/-1/1/conf/multi-solid

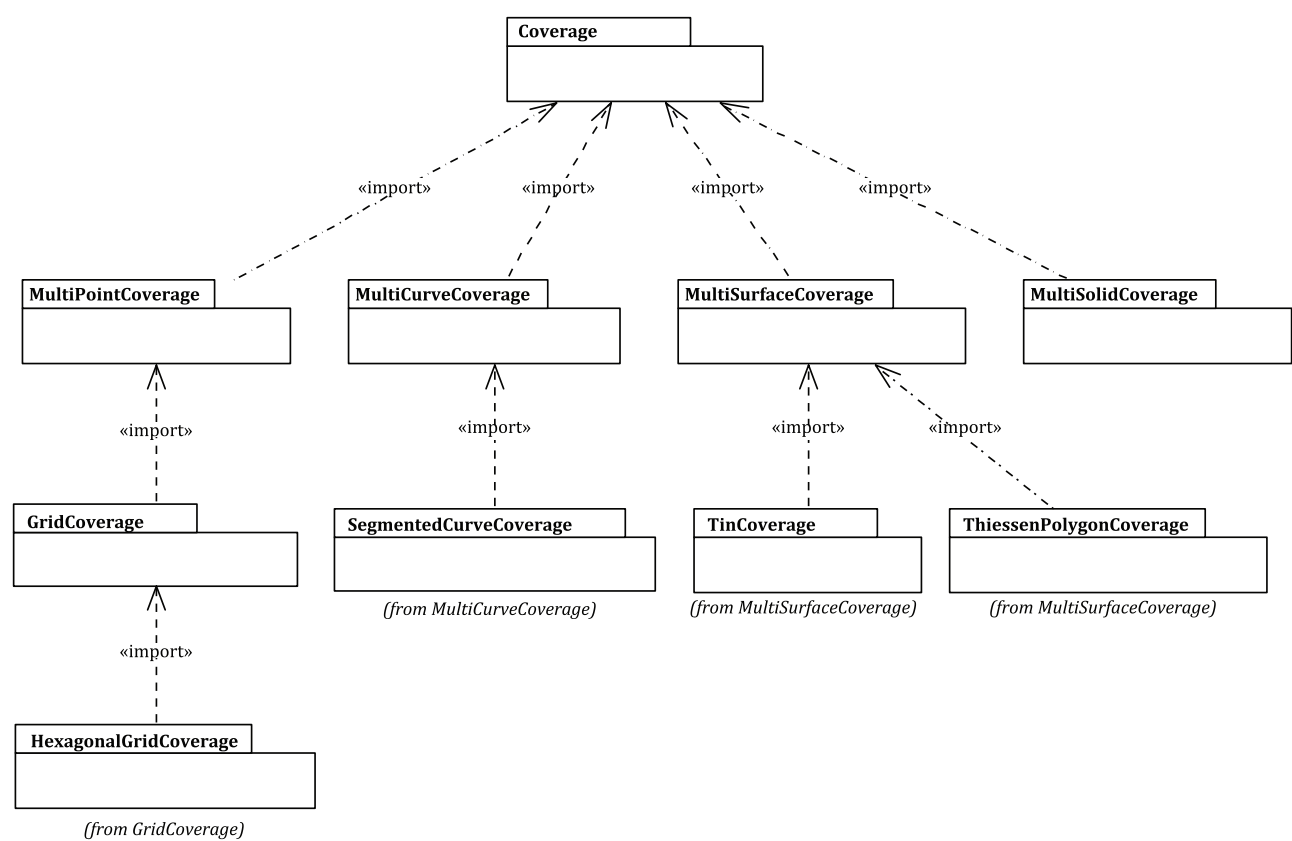


Figure 1 — Packages of the coverage schema

5 Coverages

5.1 Overview

This clause defines the conformance class Core of the package Coverage.

This document defines the term “coverage”, adopted from the Abstract Specification of the Open Geospatial Consortium,^[15] to refer to any data representation that assigns values to positions. As such, a coverage can be viewed conceptually as a function which, for every value of its domain, provides a particular value taken from its range; in fact, a coverage may provide a set of values for a particular position.

An equivalent view of a coverage is that of a set of geometric objects, located in a given space and equipped with a given attribute value. Both views are supported by this document.

Coverages are multi-dimensional by nature, such as 1D sensor timeseries, 2D x/y images, 3D x/y/t image timeseries and x/y/z geophysical information, and 4D x/y/z/t atmospheric and oceanographic information. Note that “multi-dimensional” here means “1 or more dimensions” following science and engineering nomenclature, rather than the common English understanding of “multi” being “more than one”. The dimension axes spanning the coverage can be of spatial, temporal or “abstract” nature (where abstract is understood in the sense of being neither spatial nor temporal), or any combination of these. As such, a coverage is particularly suitable for the digital representation of a given space/time varying phenomenon.

EXAMPLE 1 Point clouds can be modelled as multi-point coverages. Several observation values can be acquired for a particular location, and reading such a location will result in the set of all values observed. On a grid, on the other hand, it is ensured by definition that every grid location will have exactly one value assigned.

EXAMPLE 2 A satellite image timeseries has two spatial and one temporal axis. A geo-statistical datacube can have a spatial and temporal axis and a population density axis.

The set of locations (in a general sense) where a coverage has objects sitting and, hence, has values to offer is called the coverage’s “domain” and the locations are called “direct positions”. The set of all these values is the coverage’s “range”, described by the “range type”.

Coordinates in a coverage are all expressed in the same coordinate reference system (CRS). Based on ISO 19111:2019, such a CRS may either be defined directly (such as in the EPSG collection of CRSs^[21]) or it may be composed from several CRS definitions.

EXAMPLE 3 The CRS of a satellite image timeseries consists of two spatial and one temporal axis, in a given order. Coordinates along each axis are expressed accordingly: horizontal spatial coordinates can be expressed in degrees Latitude and Longitude, as laid down in the EPSG:4326 CRS, while time can be expressed in seconds since epoch or in a given calendar, like Proleptic Gregorian.

In terms of common data structures, coverages encompass regular and irregular grids (requirements class “Grid Coverage”), point clouds (requirements class “Multi-Point Coverage”), and general meshes (requirements classes “Multi-Curve Coverage”, “Multi-Surface Coverage”, and “Multi-Solid Coverage”).

Different views on this coverage concept exist. Therefore, several practically relevant and compatible views are explicitly supported.

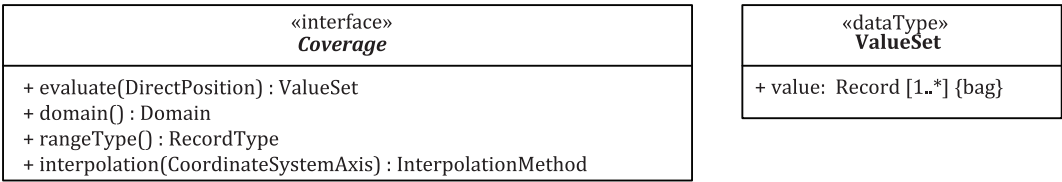
- In a mathematical view, a coverage is defined as a function $C: D \rightarrow R$ with domain D and range R which delivers some value for each element from D . This view is realized as one variant of coverage modelling in subclass CoverageByDomainAndRange (see 5.8.3).
- Geometrically, a coverage can be seen as a set of geometric objects. This view is provided as another variant in subclass CoverageByValuePair (see 5.8.2).
- In standardization terms, a coverage can be described as a set of “features” (as per ISO 19101-2). Each feature has a location and attributes. When considered together, the set of all these pairs defines the coverage’s mapping from location to values. “Geometry” here is understood in the widest possible sense, including all spatial and temporal dimensions and beyond. Features in such a collection forming a coverage must have locations expressed in the same CRS (the coverage’s CRS), and all attribute values must share the same data type (the coverage’s range type). See 5.8 for details.

5.2 Coverage packages

This clause describes the package Coverage in terms of interfaces (as per ISO 19103) of its central class, Coverage. A set of requirements for compliance with this interface description is defined that are based on the concepts of UML modelling from ISO 19103, coordinates and collections from ISO 19107, and coordinate systems from ISO 19111.

Requirement 1: <https://standards.iso211.org/19123-1/1/req/core/packages>

An instantiation of the package Coverage shall have all instances and properties specified for this package, its contents, and its dependencies for Coverage as per Figure 1 and Figure 2.



NOTE A concretization can potentially add further features. For example, ISO 19123-2 adds a metadata component.

Figure 2 — Coverage central classes

The UML interface modelling approach allows multiple different data structures to be defined which exhibit the same behaviour through the interface. Standardization targets are implementation standards based on the abstract model defined in this document. One such example is ISO 19123-2 which has concrete implementations as its standardization target. Note that in general different realizations of this document are not necessarily interoperable.

The original (now obsolete) model from ISO 19123:2005 is included as [Annex D](#), outside the Core conformance class. Any implementation standard referring to [Annex D](#) instead of [Clauses 5](#) to [10](#) (the conformance classes listed in [Table 2](#)) shall indicate this information clearly in its conformance statement.

Requirement 2: <https://standards.iso211.org/19123/-1/1/req/core/model>

An instantiation of the package Coverage shall indicate whether it realizes either [Clauses 5](#) to [10](#) or [Annex D](#).

5.3 Probing coverages: `evaluate()` function

One way to define the semantics of a coverage is via a probing function which, for some direct position coordinate expressed in the coverage's CRS, returns the set of values associated with it. This function can be defined, for a coverage C with domain D and value set V of that coverage, as:

$$evaluate_C: D \rightarrow V, evaluate_C(p) = \cup_{f \in C} f.contains(p)$$

based on the ISO 19107 `contains()` predicate.

NOTE This probing function serves for definition purposes only. Implementation is not required. In practice, another retrieval functionality is desirable, such as the OGC Web Coverage Service (WCS)^[14] bounding box subsetting and geo datacube analytics as per ISO 19123-3.

While, in general, more than one value can potentially be returned for a particular direct position, sometimes exactly one value will be delivered. This can occur in two cases, explained in the following examples.

EXAMPLE 1 In the case of a grid coverage, no two direct positions can share the same coordinates by definition, so there is always one value available via `evaluate()`.

EXAMPLE 2 More than one value per direct position can occur in several cases, such as in point clouds with two points incidentally sharing the same coordinates but having different values, or in MultiSolid coverages that overlap.

5.4 Domain of a coverage

5.4.1 Concept

The coverage domain describes the positions in the coverage's multi-dimensional space for which values are available. Within this multi-dimensional space defined by the domain's CRS, the coverage domain contains a set of geometric objects which together determine the direct positions, i.e. the locations in this space where the coverage offers a value. This description can be given through direct enumeration of the direct positions (for example, point clouds) or through containment descriptions (for example, areas and volumes), or another mechanism (for example, ground control points in sensor models). The coverage's "extent" gives a bounding box (i.e. lower and upper bounds along every coordinate axis) within which all its direct positions are located so that a quick overview on the footprint of the coverage can be obtained.

All coordinates and coordinate reference systems in this document are based on ISO 19111.

Requirement 3: <https://standards.iso211.org/19123/-1/1/req/core/coordinates>

An instantiation of the package Coverage shall make use of the ISO 19111 package RS_ReferenceSystem.

EXAMPLE 1 The space spanned in coverages representing 1D temperature measurement timeseries, 2D x/y images of the Earth surface, 3D x/y/t image timeseries and x/y/z subsurface voxel data, and 4D x/y/z/t atmospheric and ocean data, all are described through an appropriate CRS with the respective dimension.

The geometric objects in a coverage domain are not strictly confined through 3-dimensional physical space. They can be m -dimensional objects where $m \leq n$ for an n -dimensional coverage. Coverage subtypes are defined in terms of their domain types in [Clause 6](#) onwards.

EXAMPLE 2 A 3-dimensional x/y/t image timeseries datacube can be composed of 0-dimensional points (pixels). A coverage domain of dimension 3 can be composed of points, curves, surfaces or solids, while a domain of dimension 2 can be composed only of points, curves or surfaces.

5.4.2 Coordinates

For an n -dimensional coverage, $n > 0$, points in the coverage domain are addressed through n -tuples of coordinates based on the n -dimensional coverage's CRS (see [Figure 3](#)).

Often the unit of measure of an axis is numeric, such as degrees or metres or seconds. However, there can be several representations of coordinate measurements, such as degree/minute/seconds or Proleptic Gregorian calendar time/date strings. Finally, axes without any spatial nor temporal semantics, can be added (such as geo-statistics measures). Therefore, in this document, DirectPosition defining coverage coordinates takes a broader approach to coordinate values than ISO 19111 class Coordinate and ISO 19107 class DirectPosition by allowing not only numbers, but general strings.

Requirement 4: <https://standards.iso/2011.org/19123-1/1/req/core/directpositions>

Domain coordinates in a coverage shall be expressed as DirectPositions as described in [Figure 3](#).

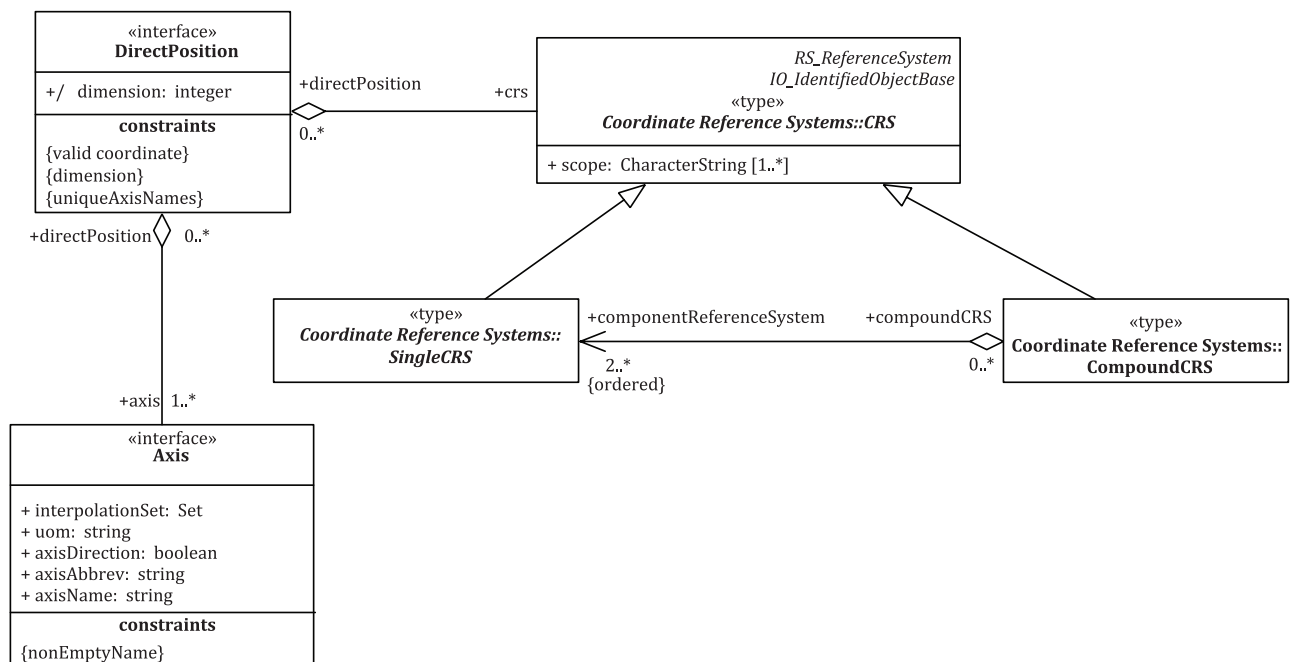


Figure 3 — Class DirectPosition

EXAMPLE The following 4D coordinate tuple illustrates different coordinate types which can possibly describe Latitude, Longitude, time, and height:

(43.001, 25, "2022-07-24", "FL100")

5.4.3 Mathematical versus physical coordinates

A coverage domain can represent physical as well as imaginary nD spaces. For example, geographic data typically have two horizontal axes, possibly one height axis (expressing altitude or depth), and possibly a time axis. Climate modelling adds a second time axis for differentiating the model run time from time modelled. By combining one or more of these axes, multi-dimensional spatio-temporal objects can be built. Further, axes can represent alternate representations of coordinate measurements. “Abstract” (in the sense of non-spatio-temporal) axes may occur as well, as in Online Analytical Processing (OLAP) where, for example, time/product/subsidiary axes are common. Additionally, bands in hyperspectral imagery often appear as a numbered sequence when there are hundreds of such bands, such as the Hyperion instrument on board of EO-1 with its 220 bands.^[25] With natural numbers, addressing becomes less wieldy.

NOTE 1 In ISO 19111, non-spatiotemporal CRSs are referred to as “parametric”. CRSs can be composed from other CRSs which can have one or more axes embedded.

NOTE 2 Spatial dimensions can potentially become non-spatial at a certain level of generalization. For example, cities in Europe can be expressed through coordinates in the first place, but then at a higher level they can be abstracted to be in Bavaria, in the Alps region, etc. which is at a symbolic level. This can be represented through dimension hierarchies like in online analytical processing (OLAP).

5.4.4 Coordinate reference systems and axes

The n -dimensional space in which a coverage resides is described by its CRS. Such CRSs often readily exist (such as in the EPSG catalogue) or they can be built by combining existing CRSs into a new, higher-dimensional one ([Figure 3](#)). Mechanisms to do so are out of scope of this document. They are defined in ISO 19111:2019.

Requirement 5: <https://standards.iso211.org/19123/-1/1/req/core/crs>

The coverage CRS shall be expressed in accordance with ISO 19111.

NOTE Sometimes there are constraints excluding some combinations. For example, Latitude and Longitude in ISO 19111:2019 always come in pairs and building CRSs that contain only one of these pairs is not permitted.

Additionally, this document establishes CRS definitions for unitless abstract spaces. The general term “index CRS” refers to a non-georeferenced CRS where all axes are numbers. This induces a family of nD CRSs which, by convention, are named index1D, index2D, index3D, etc.

For backwards compatibility, image CRS exists for the non-georeferenced case (class imageCRS in [Figure 4](#)).

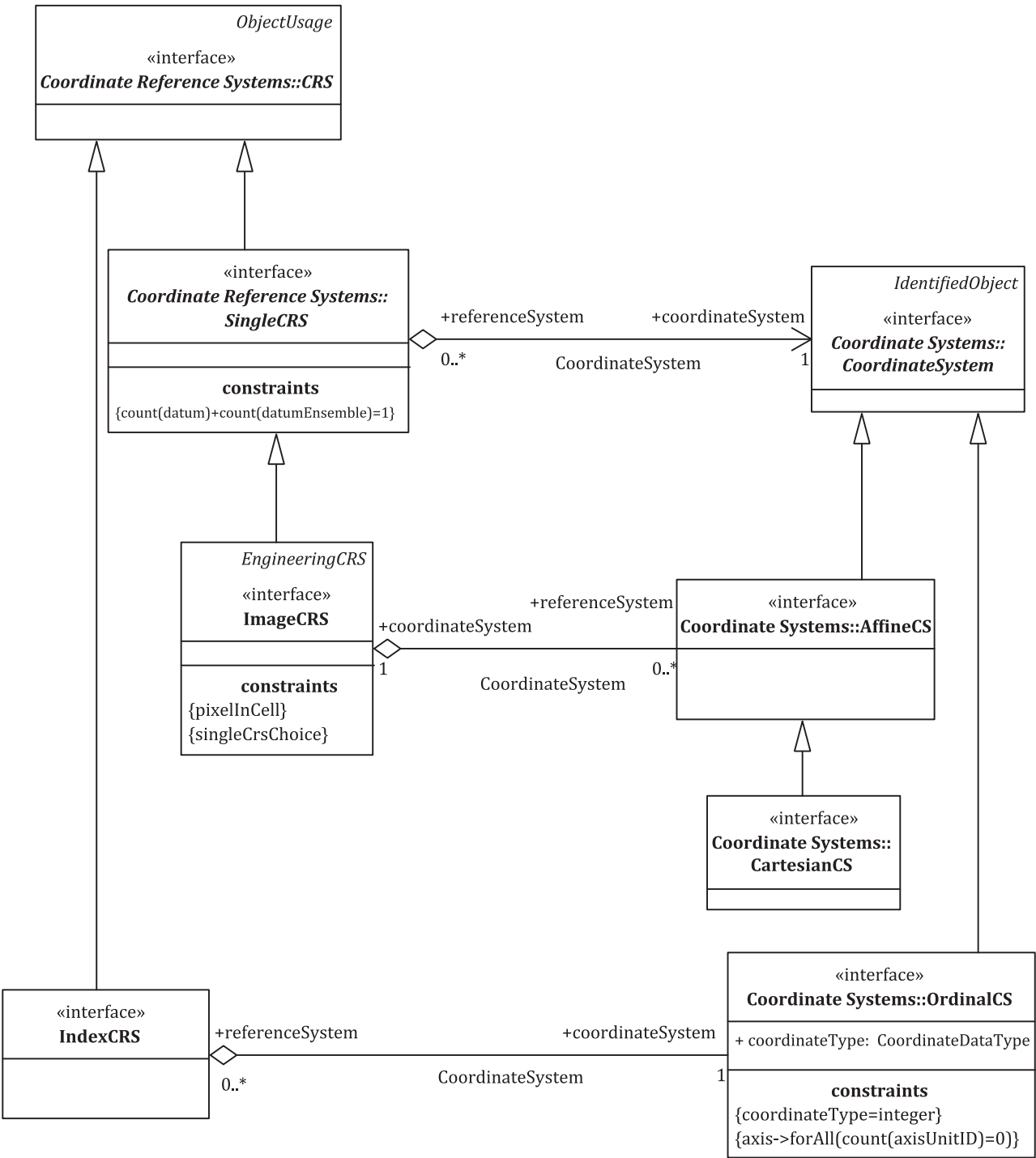


Figure 4 — IndexCRS and ImageCRS classes

EXAMPLE 1 A 4D domain can be described through axes Latitude and Longitude (given by EPSG:4326) combined with a time axis as per ISO 8601-1 combined with an indexCRS2D for spectral bands.

EXAMPLE 2 The direct positions in a coverage’s domain can be enumerated (example: point sets in a multi-point coverage) or they can be given implicitly (example: corner points indicating the set of all raster positions in a Rectified grid coverage).

In defining multi-dimensional coverage spaces, this document takes an approach where axes are first-class citizens, as opposed to ISO 19111 which operates mainly on a CRS level. Both views are consistent and compatible as CRSs describe ordered lists of axes.

For the purpose of coverages, CRS axes are enriched with further properties required for proper modelling of various coverage types, in particular, grid coverages (see 7.2).

EXAMPLE 3 The following is a non-exhaustive list of possible axes in coverage Domains:

- a CRS consisting of a single time axis can model a timeseries of measurements. Time coordinates can be expressed, among others, in seconds since epoch (often: January 1, 1970) or as time/date strings of the Proleptic Gregorian Calendar defined in ISO 8601-1, such as “2021-05-12”;
- pressure altitudes, measured in hectopascal (hPa), as well as Flight Levels, expressed in 100 feet steps (e.g. “FL150” for 15000 feet above Mean Sea Level), represent “proxies” for altitude used in aviation. In ISO 19111 this can be modelled through parametric CRSs;
- spectral frequencies can define a coverage axis. In ISO 19111 this can be modelled through parametric CRSs.

5.4.5 Coverage classification along topological dimensions

The coverage concept in this document supports a wide range of diverse coverage types. One suitable criterion for classification is along the type of feature bundled in a coverage. As feature types are commonly sorted along their topological dimensions (thereby defining points, lines, surfaces and solids in natural space) this is an appropriate criterion for classifying coverage types. Additionally, there can be further constraints, such as grid coverages where the direct positions are supposed to sit on a grid. In [Clause 6](#) onwards, coverage types sorted along their topological dimension are as defined in ISO 19107.

5.5 Range of a coverage

At every direct position a coverage holds a single value or a non-empty set of values. All of these values of a coverage together make up the coverage’s range.

EXAMPLE 1 A coverage can assign to each direct position in a county the temperature, pressure, humidity and wind speed and direction vector, at a specific time, at that point. The coverage maps every direct position in the county to a record of these fields. In this case, the common type of the coverage range values is a record of components, each of its individual type.

The range type component describes the type of the set of values available for the range. Structures such described can be atomic or a record of named components.

Requirement 6: <https://standards.iso/211.org/19123/-1/1/req/core/record>

The range type component shall be of type Record Type as defined in ISO 19103.

Requirement 7: <https://standards.iso/211.org/19123/-1/1/req/core/mininfo>

The range type of a coverage shall provide at least the information necessary to decode and process the range values:

- a) data type information in some available typing system,
- b) null values, and
- c) unit of measure.

EXAMPLE 2 RGB images, when modelled as a coverage, have as their range type a record consisting of three components red, green and blue (in that order), each of them of type unsigned 8-bit integer.

The structure of a range type definition is not specified further in this document because no commonly accepted consensus exists. However, for interoperability reasons it is highly recommended that some description be adopted, for example to differentiate height in metres from height in feet in a digital elevation model.

Recommendation 1: <https://standards.iso/211.org/19123/-1/1/req/core/measurement>

Range type definitions should rely on some commonly agreed system of description and measurement.

NOTE One way of providing this information is via a link pointing to a location that provides this information in a standardized manner. Another way is to provide this information directly as part of the coverage.

5.6 Interpolation

5.6.1 Concept

Sensors observing natural phenomena (mathematically: fields) do not collect data only at the exact point of a direct position. Rather, they integrate data over a given neighbourhood of the direct position and present the result as the value at this position. Generally speaking, observations of the field are aggregated over a given region and time. Therefore, it can make sense to invert this quantization to discrete points and derive values for in-between positions from the direct positions available in the coverage.

Through interpolation, range values can be obtained for coordinates within the domain of a coverage which are not direct positions. Basically, a coverage provides values only at its direct positions. Interpolation means applying a given algorithm to obtain a range value for locations inside a coverage's domain which are not direct positions, usually by combining the values of several direct positions in the neighbourhood of the coordinate location under inspection.

Interpolation requires the domain to be in a CRS which allows for expressing “in-between” coordinates.

EXAMPLE 1 Index coordinates, representing integer numbers, do not allow the expression of any in-between value as this would not be an integer. Conversely, Latitude, Longitude, height and time, allow the expression of values between any two given coordinates as they conceptually map to real numbers. The in-between values can be continuous (such as temperature) or discrete (such as land classification).

Depending on the interpolation method (the algorithm applied), the range type can require provision of “in between” values, too. In general, for interpolation it can be necessary for the range type to allow for arbitrary values to be generated, requiring a continuous range type. Therefore, applicability of a particular interpolation method in general also depends on the range type.

EXAMPLE 2 “Nearest neighbour” interpolation does not require new values to be generated as the resulting value is chosen from the available ones taken from the surrounding direct positions. “Linear interpolation”, on the other hand, will usually generate values different from the surrounding ones, based on the arithmetic means computation.

ISO 19107 defines a set of interpolation methods, individually for the particular geometry types, upon which this document relies.

Requirement 8: <https://standards.iso/2011.org/19123/-1/1/req/core/iso19107-interpolation>

Interpolation in a coverage shall conform with the interpolation schemes specified in ISO 19107. A reserved value shall indicate that no interpolation is applicable.

NOTE 1 Typical examples of such values include “none” or “undefined” or “nil”. However, these are not defined normatively in this document (and neither are they defined in ISO 19107). Instead, they are left to concrete instantiations of coverage data structures.

NOTE 2 Additionally, an exemplary, non-normative set of interpolation methods is presented in [Annex B](#).

Interpolation can be applied along a single axis or along several axes simultaneously. Therefore, interpolation methods on a high, conceptual level are defined on axis level. An implementation standard based on this document can potentially bundle interpolation methods to allow only one and the same interpolation method across all (or a subset of) axes.

EXAMPLE 3 In horizontal geographic CRSs, interpolation will normally be coupled so that Latitude and Longitude always share the same interpolation. Time and height, on the other hand, will normally be interpolated individually.